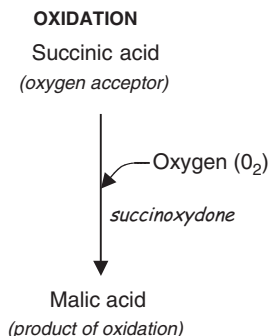


(a) Battelli and Stern (1907-14)



(b) Thunberg (1916)

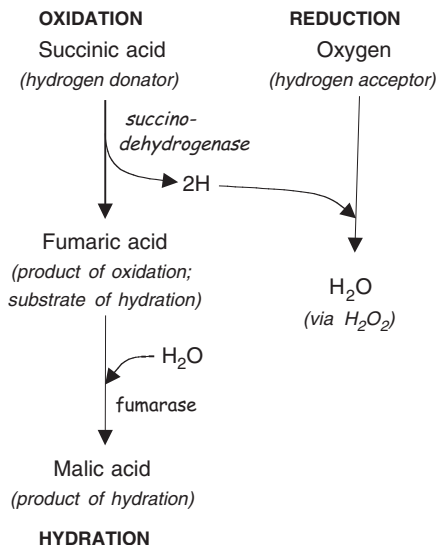


Figure 3.12. Two early accounts of the metabolism of succinic acid to malic acid. They differ in how oxidation is conceptualized and in the number of reactions involved. (a) Battelli and Stern assumed that activated oxygen is added directly to the substrate, succinic acid. (b) Thunberg identified fumaric acid as an intermediate substance between succinic and malic acids; incorporated paired reduction-oxidation reactions, as proposed by Wieland; and posited specific enzymes for which better evidence later emerged. It was also determined later that the carrier coenzyme FAD, not molecular oxygen, was the immediate hydrogen acceptor.

Wieland's proposal received little uptake from biochemists until it was further developed by Thorsten Ludvig Thunberg, who recognized that it could be applied to the experimental results that Federico Battelli and Lina Stern (1911) had obtained concerning the oxidation of succinic acid. Their approach was to add metabolic substrates to suspensions of minced animal tissue presumed to include enzymes of interest, and use manometers to supply oxygen gas and measure how much was absorbed during the resulting oxidation reactions. As illustrated in Figure 3.12(a), they interpreted their findings on succinic acid in terms of an enzyme that *activated* the dissolved oxygen so that it would combine with the substrate (succinic acid) to yield the observed product (malic acid).<sup>40</sup> Subsequently, however, Hans Einbeck (1914) demonstrated that fumaric acid was created in the process:

<sup>40</sup> The named the enzyme *succinoxydase*, using an alternative to the traditional ending – *ase* since this enzyme was not soluble.